MULTI-PATH ULTRASONIC METER DIAGNOSTICS FOR FIELD VERIFICATION

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Abstract Most customers have now started to use ultrasonic meters for natural gas custody transfer metering. As a stand-alone meter, it can give numerous diagnostics information on the performance of the meter, but not enough to determine a benchmark on its performance to a certain reference. This is where external diagnostic would be required to enhance customer's confidence in the overall metering system performance. In this paper, we will focus on these various techniques, and how they are being used.

Before we touched on the field verification using SOS on flow computer, we will highlight some of the recent developments in the improving the performance and diagnostics of ultrasonic metering system. They are :

- Enhanced/Improved Wet Flow Calibrations
- Improved Diagnostic Software
- Incorporate Speed of Sound (SOS) calculation in flow computers for on-line verification
- Remote Diagnostic

We will end with an example and an update on the latest development in AGA-9 [1] Working Group.

1 INTRODUCTION

Most customers have now started to use ultrasonic meters for natural gas custody transfer metering. As a stand-alone meter, it can give numerous diagnostics information on the performance of the meter, but not enough to determine a benchmark on its performance to a certain reference. This is where external diagnostic would be required to enhance customer's confidence in the overall metering system performance. In this paper, we will focus on these various techniques, and how they being used.

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2 ENHANCED/IMPROVED WET FLOW CALIBRATIONS

The initial wet flow calibrations are based on 6-points or 8-points and corrected on a single Flow-Weighted-Mean-Error (FWME) curve. With the need to improve the accuracy and reduce the uncertainty, flow laboratories have implemented various corrections, such as polynomial correction curve fit, and recently, the multi-point linearization method, are being adopted. Figure 2.1 shows the single FWME curve.

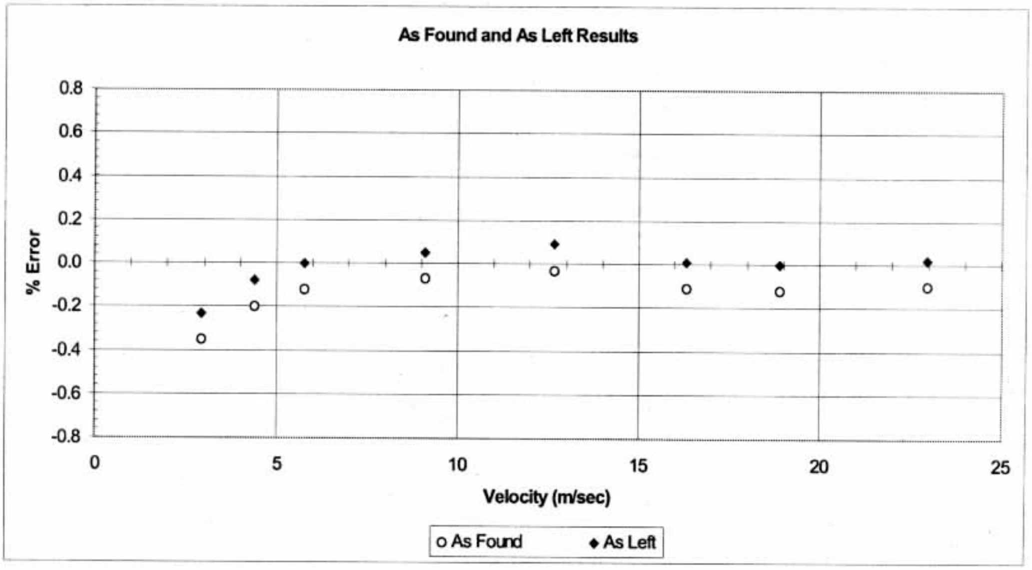


Figure 2.1 - Single FWME Curve

This enhanced and improved wet flow calibration reduces the uncertainty of the meters, as it tries to adjust the measured value to its true value. Figure 2.2 shows the polynomial correction curve before and after adjustment.

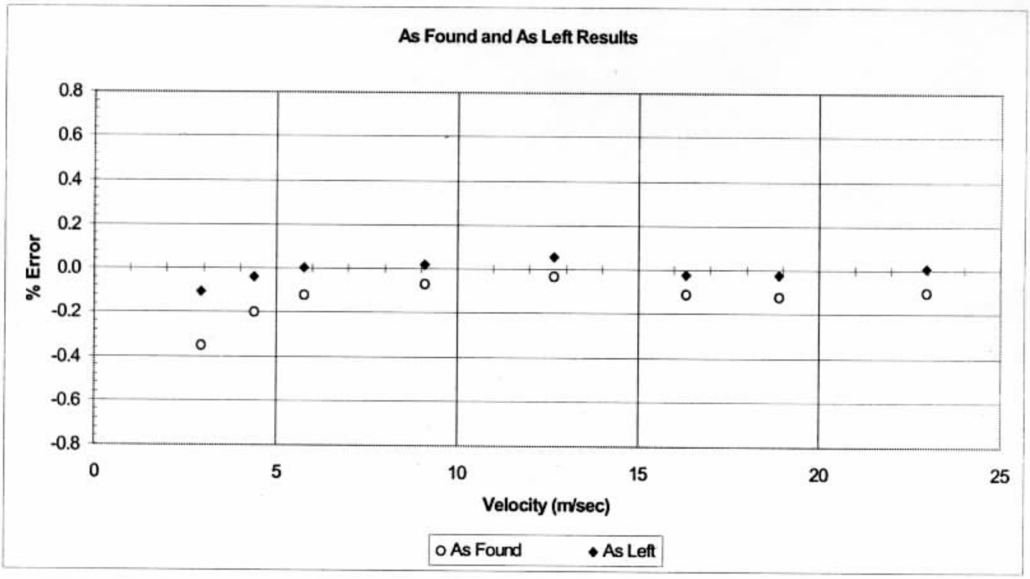


Figure 2.2 - Polynomial Correction Curve

Another method in correcting the meter to the zero-error baseline is the Multi-Point Linearization. This method is not new, as it is being done on turbine meter calibration. Figure 2.3 shows how the points will be adjusted after linearization.

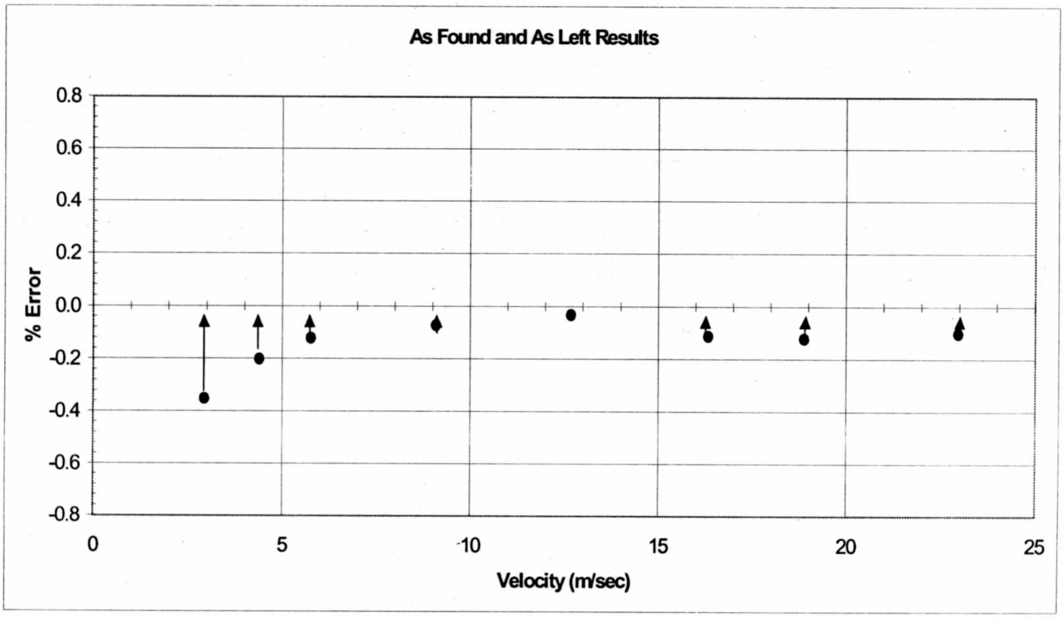


Figure 2.3 - Multi-Point Linearization Method

A meter factor will be assigned at each calibrated point, and hence, the 'As Left' should be a straight line.

3 IMPROVED DIAGNOSTIC SOFTWARE

Diagnostic software has also improved over the last few years. The use of this software is to determine the status of the meter's performance, as well as for troubleshooting purposes. The information obtainable from this software are mainly :-

- Gains
- Signal Quality
- Signal to Noise Ratio
- Speed of Sound
- Velocity Profile
- Individual Chord Waveform

The latest CUI (Customer Ultrasonic Interface) software not only gives the above information, but also provides numerous features allowing easier operation and configuration of Ultrasonic meter parameters.

These new features are :-

- Configuration of new USM through wizard setup. Figure 3.1 shows the Wizard setup screen.
- Single page Witness and Inspection Report. This report indicates the meter's main configuration, as well as a snap shot of the performance, and can be signed off by customer. Figure 3.2 shows the report.
- Single Screen on monitoring Meter's Performance. Figure 3.3 shows the Meter Monitor screen.
- USM configuration verification. This compares the meter's configuration to a master configuration in PC/laptop hard drive. Figure 3.4 shows an example.
- Merging Log Files.
- Speed of Sound (SOS) calculation.
- Remote diagnostic.

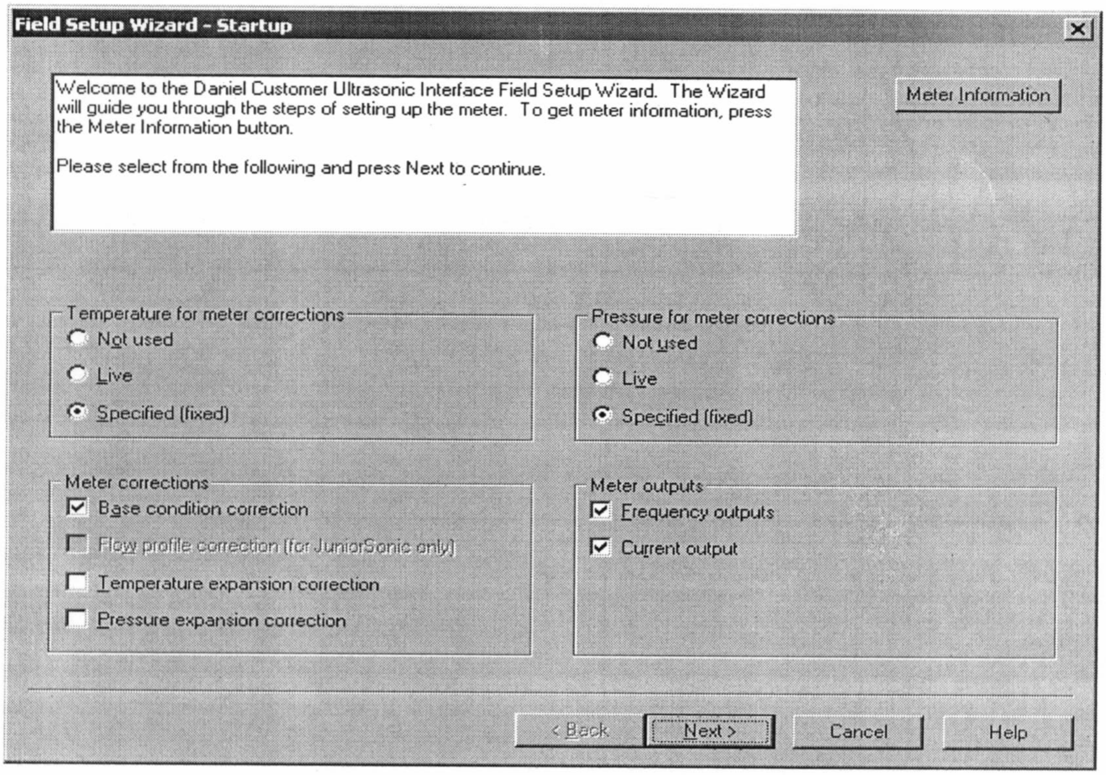


Figure 3.1 - CUI Meter StartUp Wizard Screen

Daniel Ultrasonic Meter Test and Inspection Report Summary

Station Name:	Your Favorte Station	Co. Name:	Your Favorite Company	Test Date:	1/6/2002
Meter Name:	Your Favorite Name	Date last tested:	6/19/2000	Test Time:	11:48:00
Technician:	Your Technican #1	Technician:	Your Technican #2	Test Duration:	50 Data Points
Address:	Your Favorite Street	City:	Any Town	State/Country:	Any State

Meter Serial No:	01-230468	Volume Full Scale for Freq:	180,000 ACFH	Meter Contract Hour:	0 (Military Time)
Inside Diameter:	18.8120 Inches	Freq. Full Scale:	5,000 Hertz	Average Performance:	100 %
Pressure:	846 PSIG	K Factor:	100.00000 Pulses/CF	Meter Average SOS:	1396.13 fps
Temperature:	63.1 Deg. F	Vol/Pulse:	0.0100000 CF/Pulse	Computed SOS:	1395.00 fps
Batch Size:	20	Volume Full Scale for Current:	180,000 ACFH	Percent Difference:	0.081 %
Stack Size:	0	Low-Flow Cutoff:	0.1 ft/sec.	Flow Direction:	Forward
		Output Update Rate:	5.00 Seconds	**Profile Factor:**	1.1912

Velocities	**Average**	**Maximum**	**Minimum**
Path A:	49.5	52.8	45.9
Path B:	62.3	66.3	58.0
Path C:	67.6	71.8	63.1
Path D:	59.5	63.3	55.4
Meter Avg.:	**61.9**	**65.8**	**57.8**
SOS			
Path A:	1,397.4	1,399.2	1,396.2
Path B:	1,395.8	1,397.6	1,394.7
Path C:	1,395.2	1,396.9	1,393.9
Path D:	1,396.2	1,398.0	1,395.2
Meter Avg.:	**1,396.1**	**1,397.9**	**1,395.0**

Other Path Diagnostic Averages	% Perf.	Gain	SNR
Path A Up:	100.0	125.7	70,277
Path A Dn:	100.0	126.7	61,413
Path B Up:	100.0	147.6	10,317
Path B Dn:	100.0	148.4	7,847
Path C Up:	100.0	122.6	69,314
Path C Dn:	100.0	120.0	81,890
Path D Up:	100.0	133.3	32,271
Path D Dn:	100.0	127.2	46,013

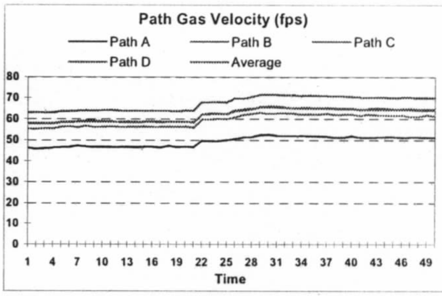
Meter Calibration Factors

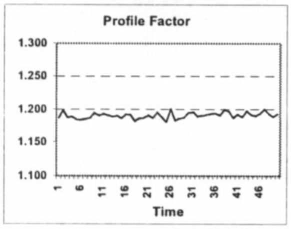
BG Factor:	0.99300
Mtr. Factor:	1.00000
Forward Coefficients	
A0:	0.003
A1:	1.00245
A2:	0.000215
A3:	0.000000
Reverse Coefficients	
A0:	0.000
A1:	1.00000
A2:	0.00000
A3:	0.000000

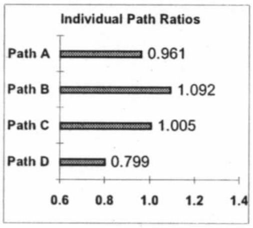
Multi-point Linearization Coefficients

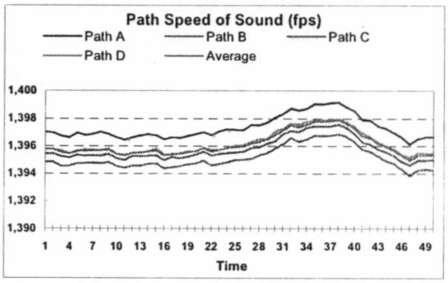
Data Point	Forward Flow Rate: Flow Rate	Forward Flow Rate: Meter Factor	Reverse Flow Rate: Flow Rate	Reverse Flow Rate: Meter Factor
1	180,000	1.0014	180,000	1.0014
2	160,000	1.0028	160,000	1.0028
3	140,000	1.0002	140,000	1.0002
4	110,000	0.9989	110,000	0.9989
5	85,000	0.9983	85,000	0.9983
6	65,000	1.0002	65,000	1.0002
7	30,000	1.0004	30,000	1.0004
8	15,000	1.0001	15,000	1.0001
9	10,000	0.9989	10,000	0.9989
10	5,000	0.9975	5,000	0.9975

Additional Averages	
Gain Up:	132.3
Gain Dn:	130.6
SNR Up:	45,545
SNR Dn:	49,291









Path Alarm Codes	
Path A	0
Path B	0
Path C	0
Path D	0
Various Status Codes	
System	0
Power Fail	0

Average Gas Velocity:	61.92 fps
Avg. Actual Flow Rate:	162,436 ACFH
Avg. Corrected Rate:	28,133 MSCFH
Avg. Path SOS Diff.:	2.2 ft/sec.
Max. Path SOS Diff.:	2.2 ft/sec.
Configuration Verified? (Y/N):	
Meter Contract Hour Verified? (Y/N):	
Historical Events/Alarms Reviewed?	
Historical Events/Alarms Collected?	

Remarks: ____________________

Signatures

Tester: ____________ Witness: ____________ Date: ____________

Figure 3.2 - CUI Single Page Witness and Inspection Report

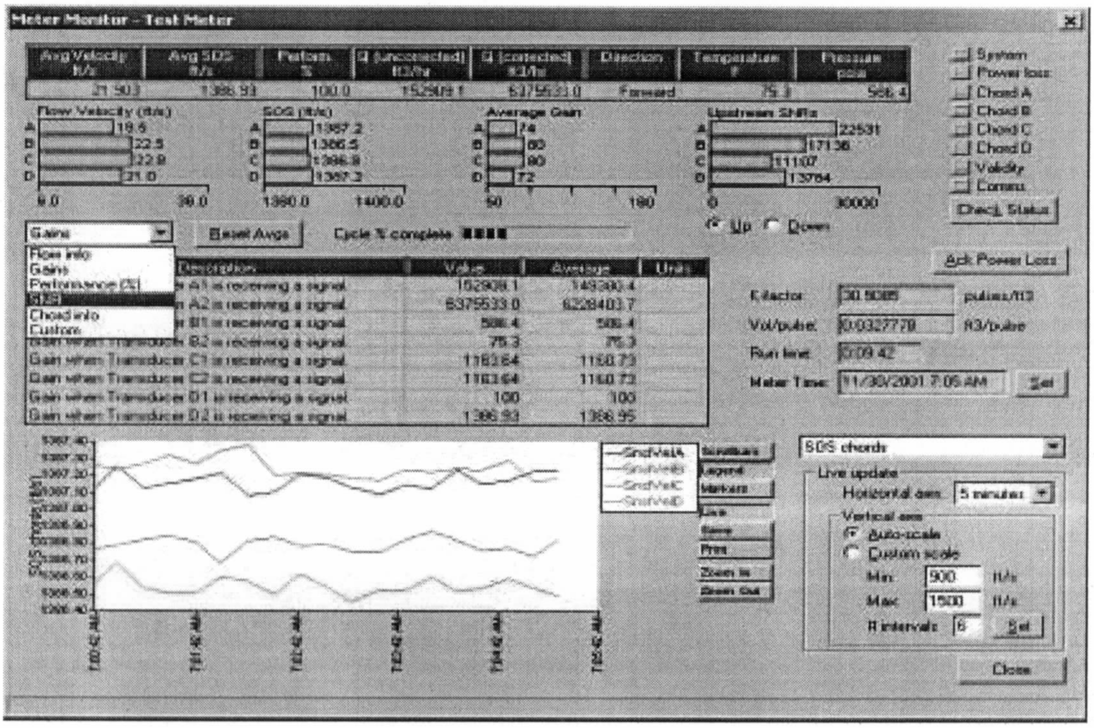


Figure 3.3 - CUI Meter Monitor Screen

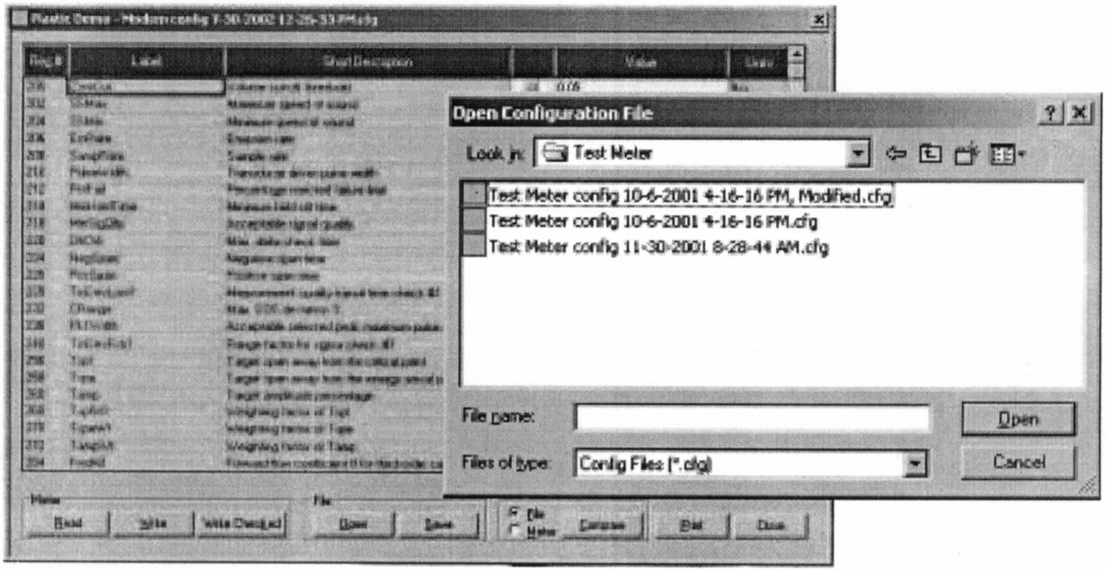


Figure 3.4 – Meter Configuration Comparison

In order to access the information from the ultrasonic meter, a Personal Computer (PC) or laptop will be required. All access to the meter should preferably be direct from PC or laptop, and not through the flow computer. Since the meter would be installed in the field, and the flow computer and PC/laptop would be operated in the control room, the ultrasonic meter shall have two serial ports, preferably both RS-485 serial link.

4 INCORPORATE SPEED OF SOUND CALCULATIONS IN FLOW COMPUTERS FOR ON-LINE VERIFICATION

Most of the features in the CUI software are for Ultrasonic meter's internal diagnostic. However, without any comparison with a baseline, it is not possible to verify its performance. Therefore, we have to find another means to verify this performance.

As per our presented paper [2], we can use the meter's measured speed of sound (SOS), and compare against a calculated SOS. AGA-10 [2] was established as a guideline, in ensuring a common method to calculate the SOS.

As mentioned in the presented paper [2], transit time is the primary measurement for the meter to determine the velocity. Should this transit time be incorrect, the meter's output will be incorrect, and so will the speed of sound. Therefore, verifying periodically the meter's measured speed of sound with an independently computed value is important.

To compute the SOS, gas composition (from Gas Chromatograph), operating pressure (pressure transmitter) and temperature (from temperature transmitter) are required. Based on these data, it is obvious that these values are obtainable from the flow computer. Hence, it is possible to calculate the SOS on-line in the flow computer, and compare continuously with the measured SOS from the USM.

By setting a deviation alarm limit, an operator can then access to both the diagnostic software for USM (CUI) and GC (MON2000) to determine the causes. Similar to CUI, MON2000 is a Window-based software to perform diagnostic on Daniel Gas Chromatograph.

5 REMOTE DIAGNOSTIC

In most installations, the operators are able to access the diagnostic software and perform maintenance or troubleshooting directly on the USM. However, there are cases where the site is far away, and not easily accessible. Or if there is a need to perform troubleshooting by the manufacturer's personnel in the office, without having to go to site, remote diagnostic is the way to go.

The USM electronics can be set up with an internal modem, and gets connected to a direct or lease line. Using the CUI software, anyone can dial in through the line and access the USM.

In addition, if the FloBoss S600 flow computer is on the ethernet line, it is also possible to access the USM limited data through the flow computer, provided there is a serial link between the flow computer and the USM.

In this manner, service support can be provided remotely, without travelling to site, and be able to investigate/troubleshoot from the office. Once it is identified that the fix is not simple and will need a site visit, at least, the engineer can pinpoint the possible causes, and have the necessary tools/equipment/spares available when travelling to site. Figure 5.1 and Figure 5.2 shows the CUI screens for the modem connection on remote access.

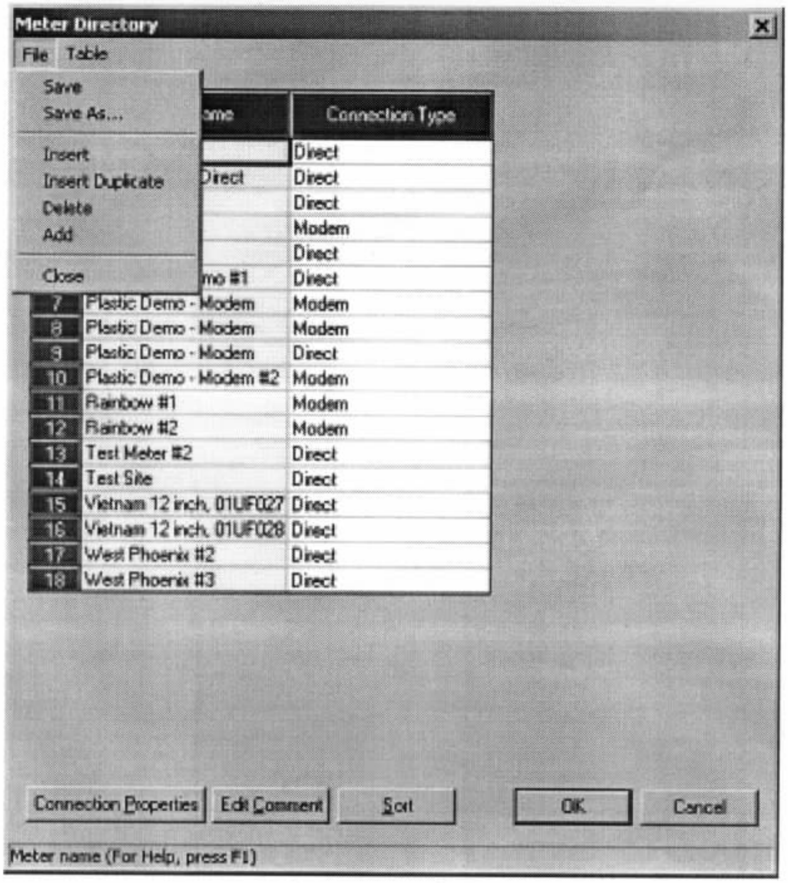


Figure 5.1 - Setting Up of Connection Type on CUI

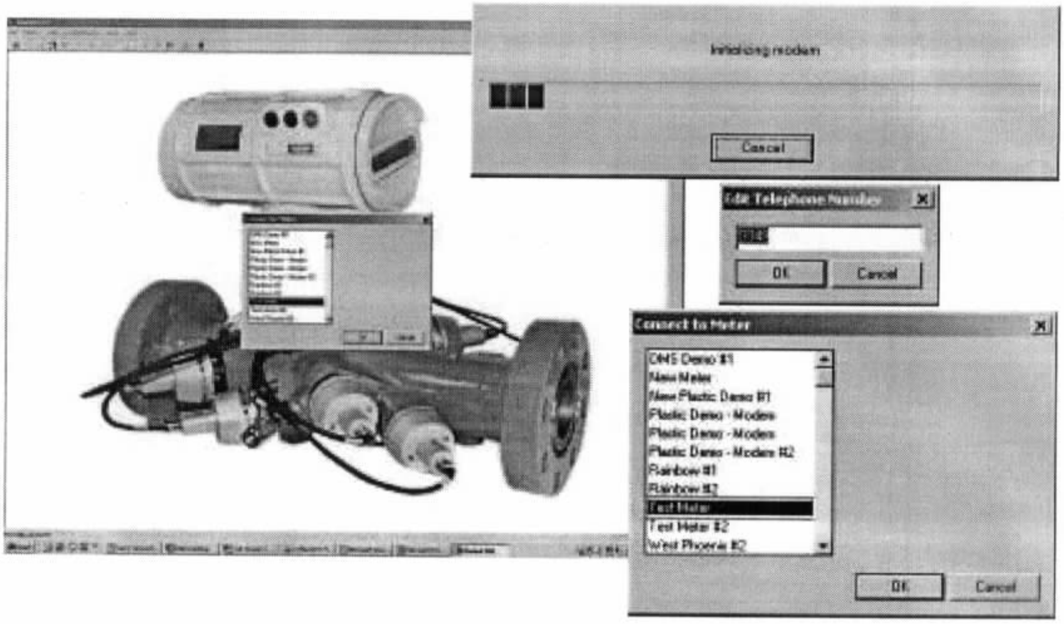


Figure 5.2 - CUI Screen with USM Connected via Modem (Remote Access)

6 CONTINUOUS ONLINE VERIFICATION OF MEASURED SOS WITH CALCULATED SOS IN FLOW COMPUTER

The details on how the test is done are not provided here. Instead the outline of the verification shall be presented.

The configuration of the metering skid is based on both ultrasonic meters in series, ie. the duty and reference ultrasonic meter are both in a straight pipeline. There are bypasses to isolate the flow through either one of the meters for maintenance. In this configuration, both meters experienced the same flow profile, since there are no elbows or bends into between the two meters. See the sketch as in Figure 6.1.

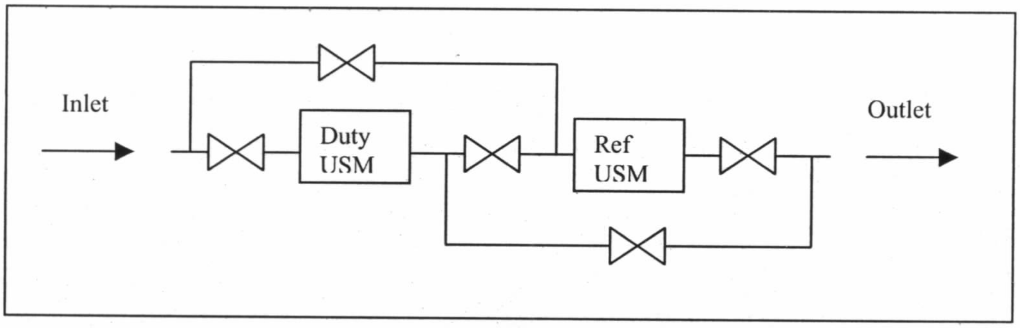


Figure 6.1 - Sketch of Metering Skid

The gas chromatograph, pressure and temperature transmitter's signals are connected to flow computer, and a RS-485 serial link between the USM and flow computer. Other than the flow computation in volume and energy, the flow computer also calculates the SOS in accordance to AGA-10.

Since the sensitivity of speed of sound change is a function of the changes in gas composition, temperature and pressure, it is important to ensure the Gas Chromatograph, temperature and pressure transmitters are validated prior to performing this verification.

It is also important during the instruments' validation, more data points are collected to compute an average value, rather than rely on a single point.

On the on-line SOS comparison, it is collected on every 10 minutes basis for about 4 hours.

The comparison is the average measured speed of sound against the calculated speed of sound. Both readings were taken from the flow computer. Figure 6.2 shows the results in 4 hours.

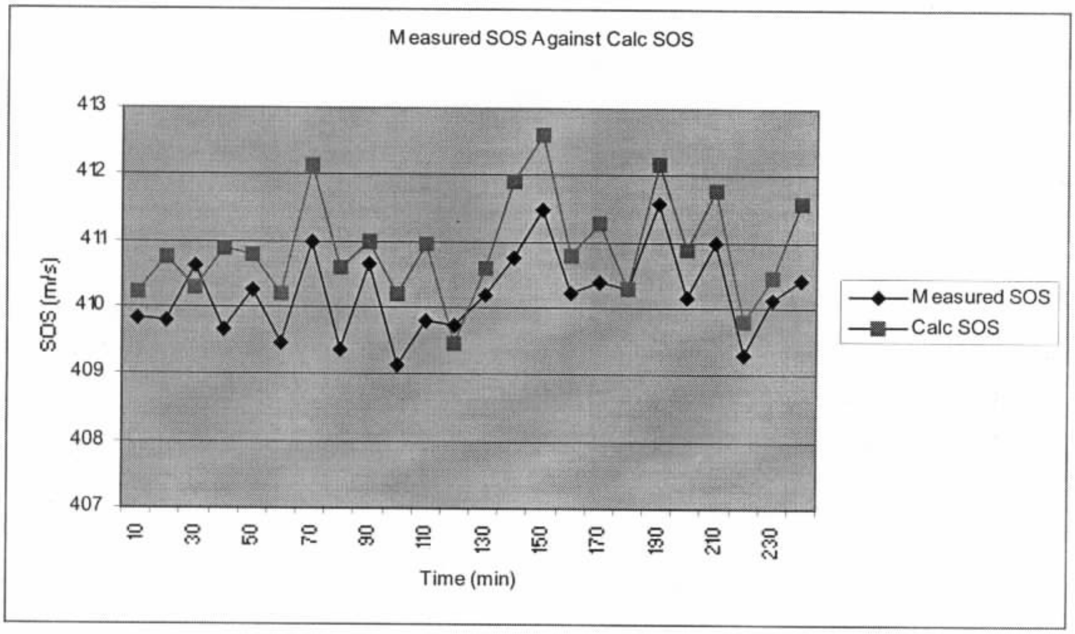


Figure 6.2 - Measured SOS Against Calculated SOS

From the chart above, it can be shown that continuous monitoring of the measured SOS with the calculated SOS helps in providing a means to check the performance of the ultrasonic meters immediately. Once if the alarm set point for deviation between the measured SOS and calculated SOS is exceeded, an alarm will be raised, and immediate attention can be taken.

Previously without this on-line comparison check, manually calculated SOS would be required, and this takes a lot of time. Furthermore, pressure, temperature, and gas composition values have to be taken before any calculations can be performed.

7 AGA-9 Working Group Topics

The current AGA-9 is only a recommended practice and not a standard. As such, an AGA-9 Working Group is setup to review the report and determine if there are any changes, addition or deletion required.

The various topics in progress are :-

- Review Performance (Accuracy) Requirements
- Expand Flow Calibration Procedures
- Auditing Meter Configuration / Calibration Factors
- Meter / Flow Conditioner Qualification Procedure
- Pressure / Reynolds Number Considerations for Flow Calibrations
- Transducer/Electronics Change-Out Qualification
- Speed of Sound Calculation Requirements
- Temperature Measurement
- Effects of Dirt Accumulation
- Standard Installation Requirements
- Ultrasonic Noise Interference
- Wall Step Changes / Wall Roughness Requirements

Once the work is completed, revision on the current release in 1998 can be expected.

8 CONCLUSION

From the above information given, improvement in the wet flow calibration helps in reducing the uncertainty of the meters, while for the improved diagnostic software, the operators will have better tools to perform troubleshooting. Therefore, it is clear that using the diagnostic software, coupled with the continuous on-line speed of sound comparison between the measured SOS and calculated SOS, it is possible to ensure the ultrasonic meters are indeed working well in the field. However, in case of unforeseen circumstances where failures are encountered, it is easy to identify the causes using the diagnostic software available. In addition, with the remote access capability on the meters, initial investigation of the fault can be identified and proper spares could be brought to site, if a site visit is required.

9 REFERENCES

[1] AGA Report No. 9, Measurement of Gas by Multipath Ultrasonic Meters, June 1998.

[2] Kevin Chin, Field Verification of Multi-Path Ultrasonic Meter With Gas Chromatograph, South East Asia Hydrocarbon Flow Measurement Workshop, 2001.

[3] AGA Report No. 10, Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases, July 2002.